Contributions to HiLiftPW-2 from Metacomp Technologies, Inc.

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DLR F11 Flow Predictions

Solver configuration

- CFD++ : Unified Grid Finite Volume solver
- Unstructured Mixed-Element cell based
- 2nd order HLLC Riemann solver
- Preconditioned
- Multigrid Acceleration
- Fully turbulent

Cases studied

C1 (Grid convergence):

7° and 16°
k-ε-Rt, SA, SST
Effects of preconditioner

C2a and C2b (Polar):

SA

DLR F11 Flow Predictions

Turbulence Model	Freestream Turbulence Level (%)	Eddy viscosity Ratio (μ_t/μ)	Remarks
k-ε-Rt	0.05	20	no freestream μ_t decay
S-A	--	1	no freestream μ_t decay
SST	0.05	20	

DLR F11 Flow Predictions

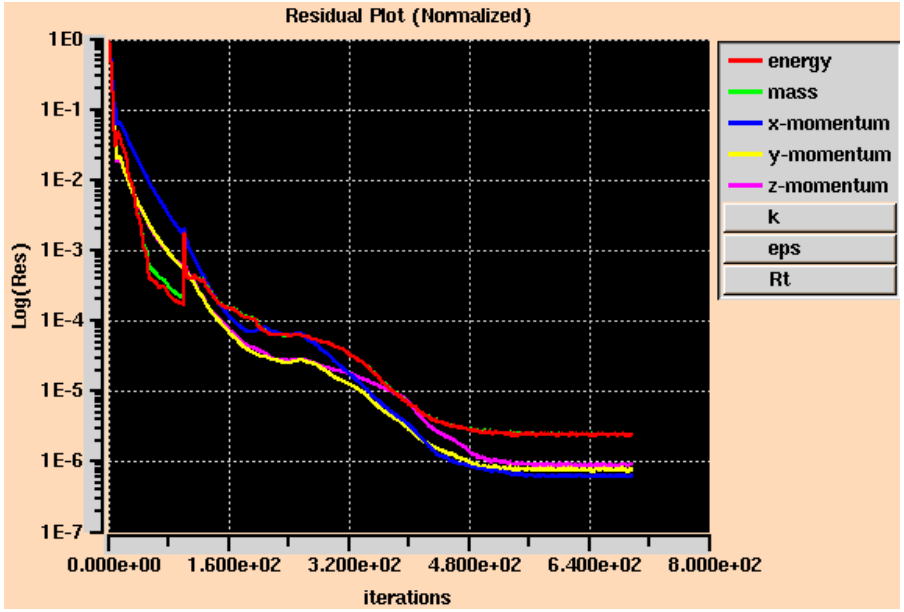
Solution information (Case 1 medium grid, 32M cells, unstructured hexa)

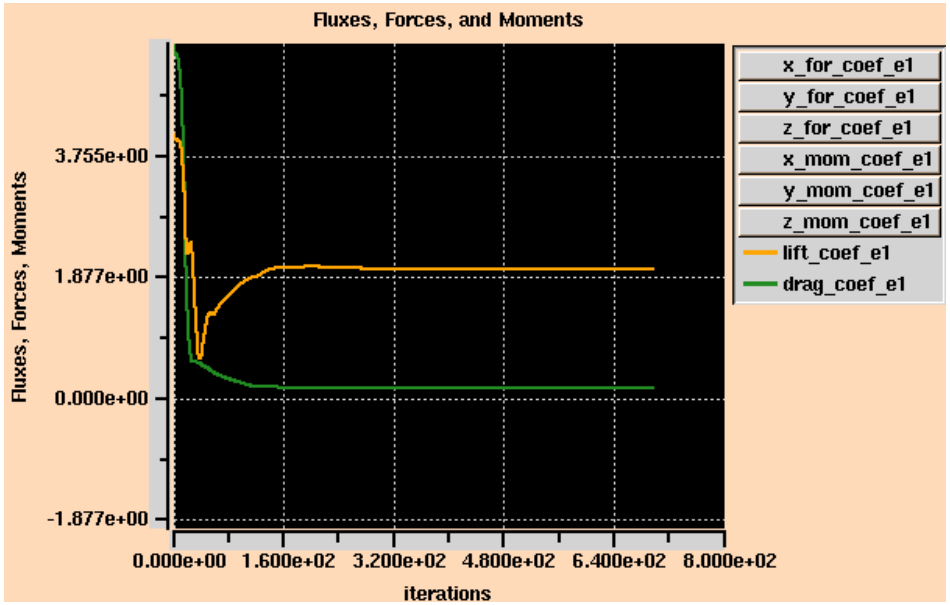
- **Hardware / platform:**
  Up to 14 nodes used
  Each node: 2 AMD Opteron 6172 (12 cores), 128 GB ram
  Up to 336 cores used
- **Operating System:** Centos/Redhat OS 5.5
  Compiler: gcc 3.2.3

- **Run Time:** 700 steps, incl. files outputs, 7.5 hours (288 cores)
  Memory used: ~560 MB/process, 107 GB total (288 cores)
  Lift and drag converged in 500 iterations or about 5 hours

Case 1 – Grid sensitivity

Typical convergence history with k-ε-Rt model



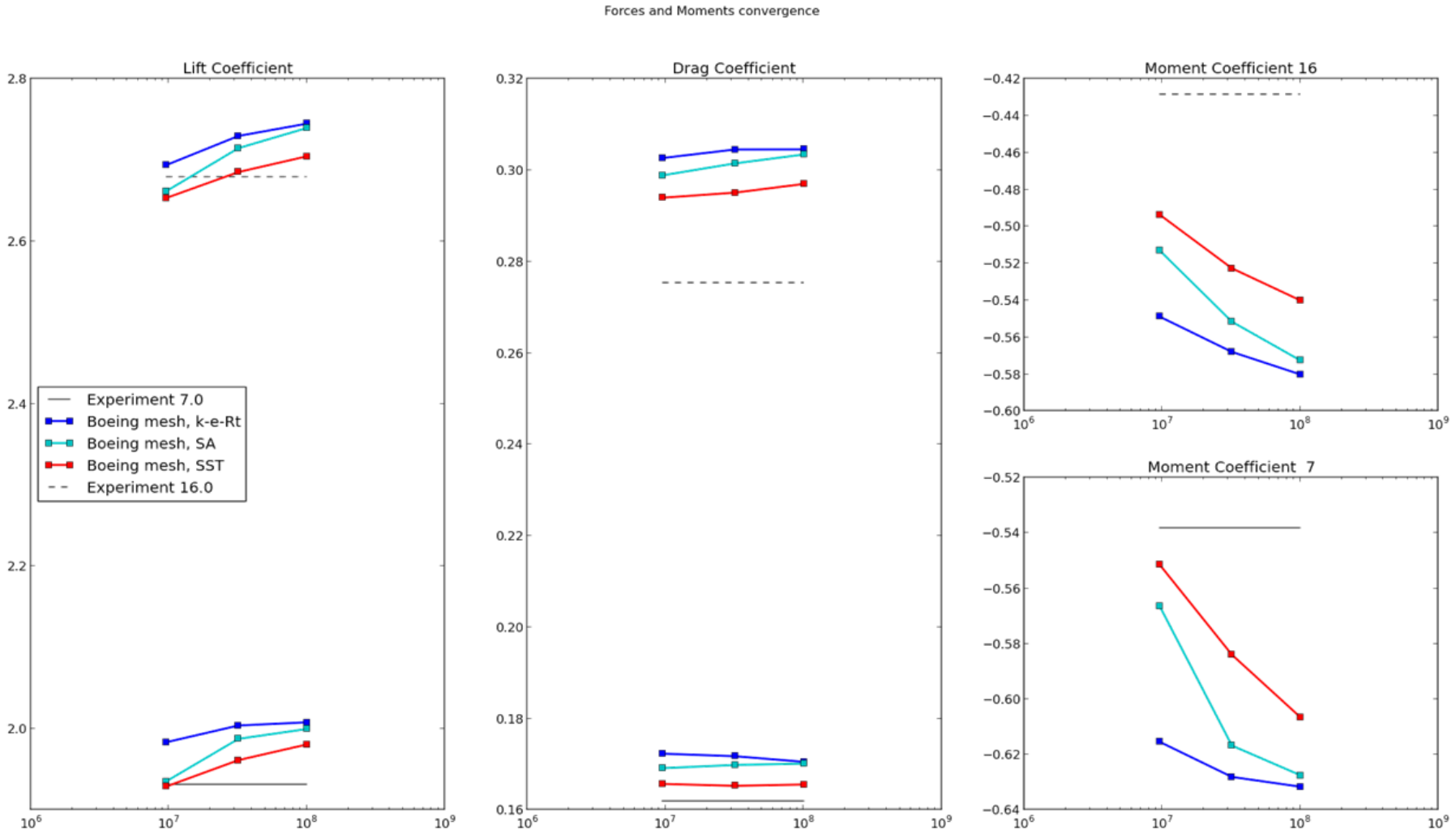


Case 1 – Grid sensitivity

- Hexa mesh (coarse, medium, fine grids)
- ICEM (A_uns_1to1_Case1Config2_v2)

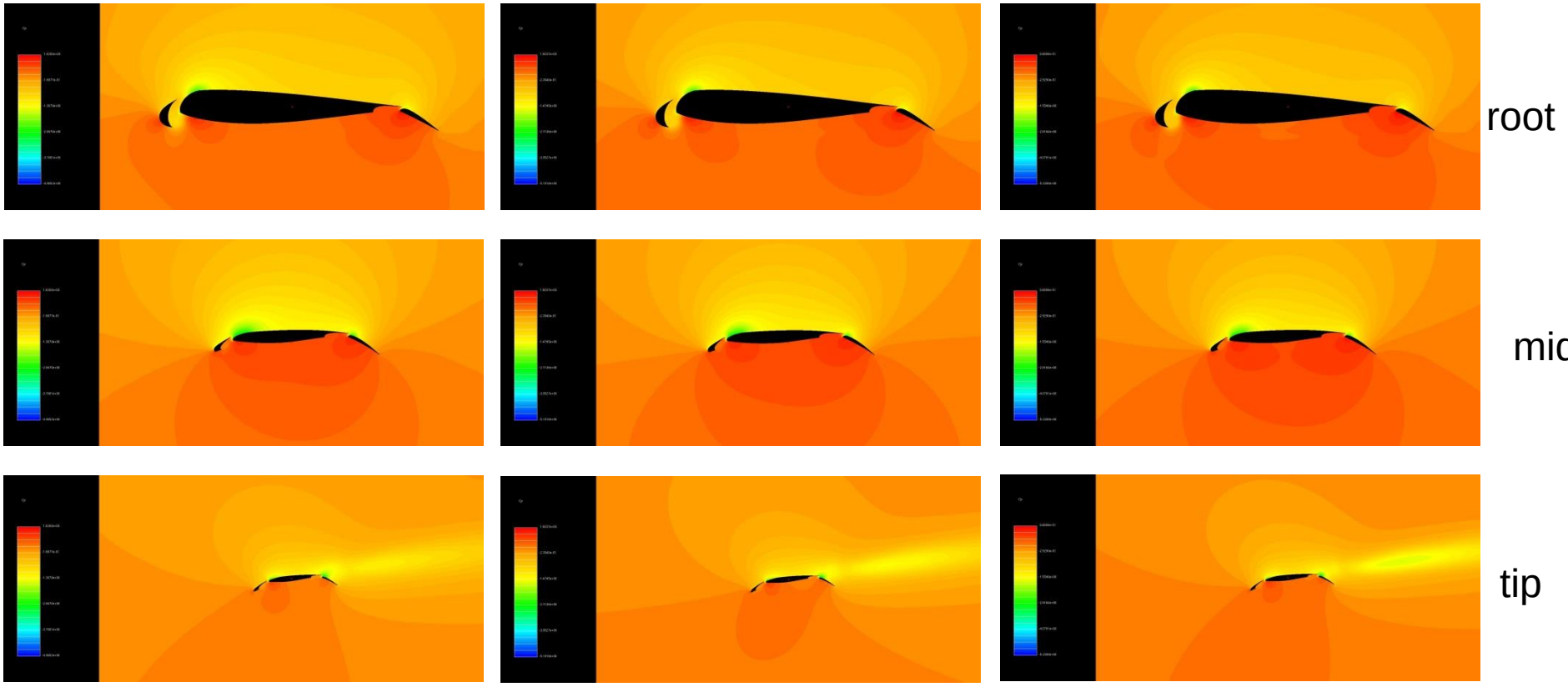
MESH	No. of cells
Coarse	9,556,725
Medium	31,998,440
Fine	100,561,536

Case 1 – Grid sensitivity

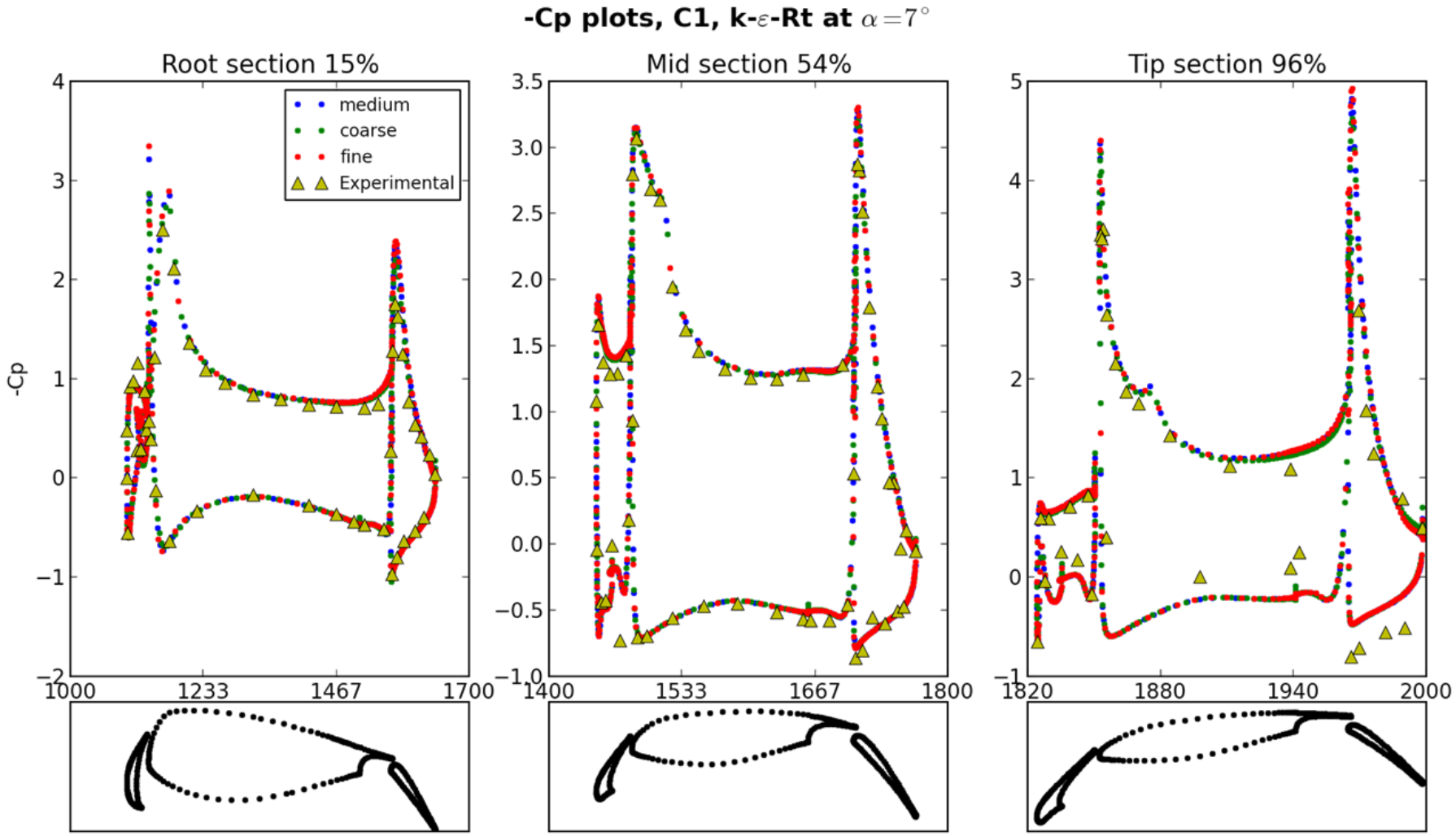


Case 1 – Grid sensitivity

$\alpha = 7°$, k-ε-Rt

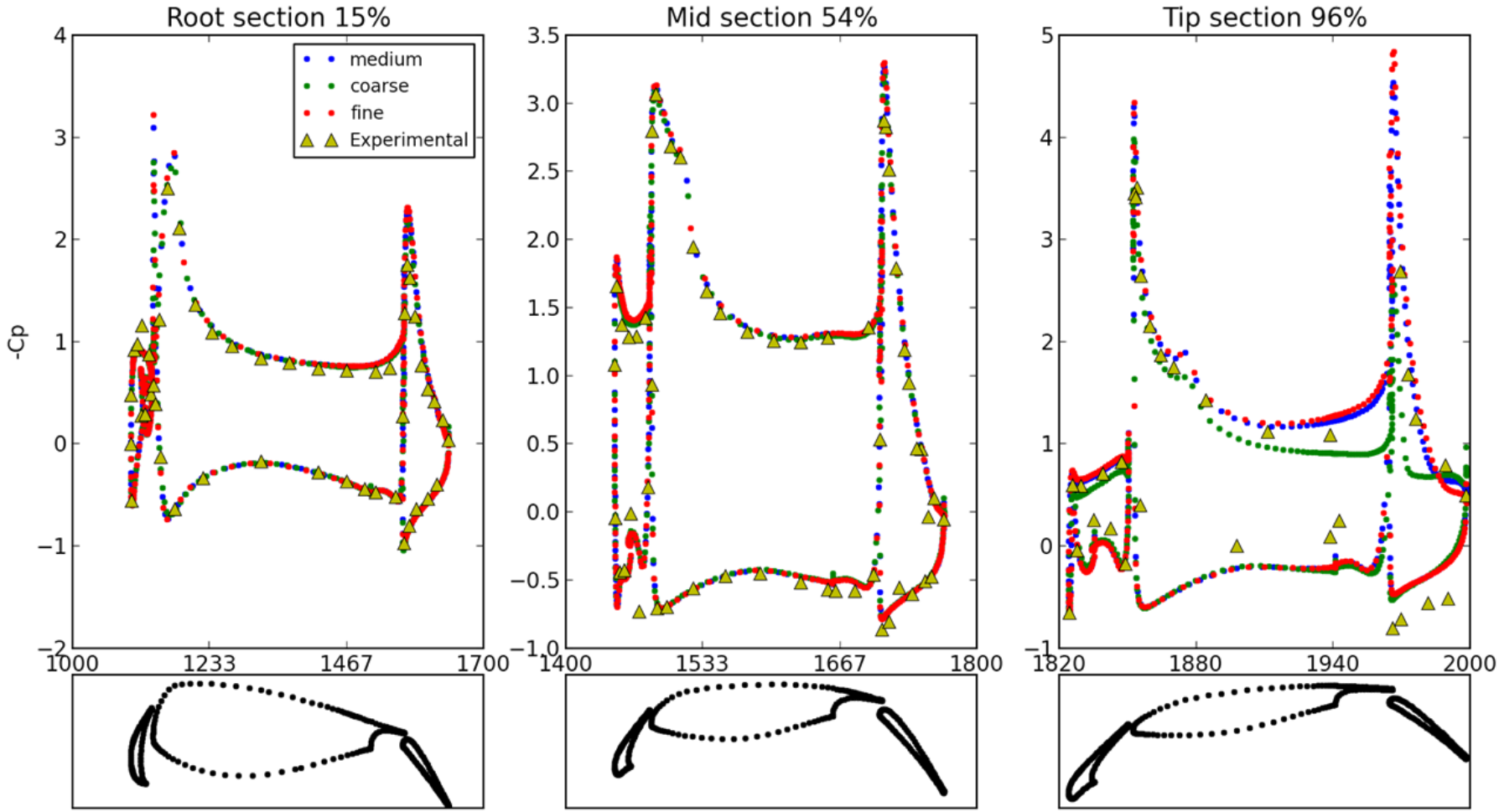


Case 1 – Grid sensitivity



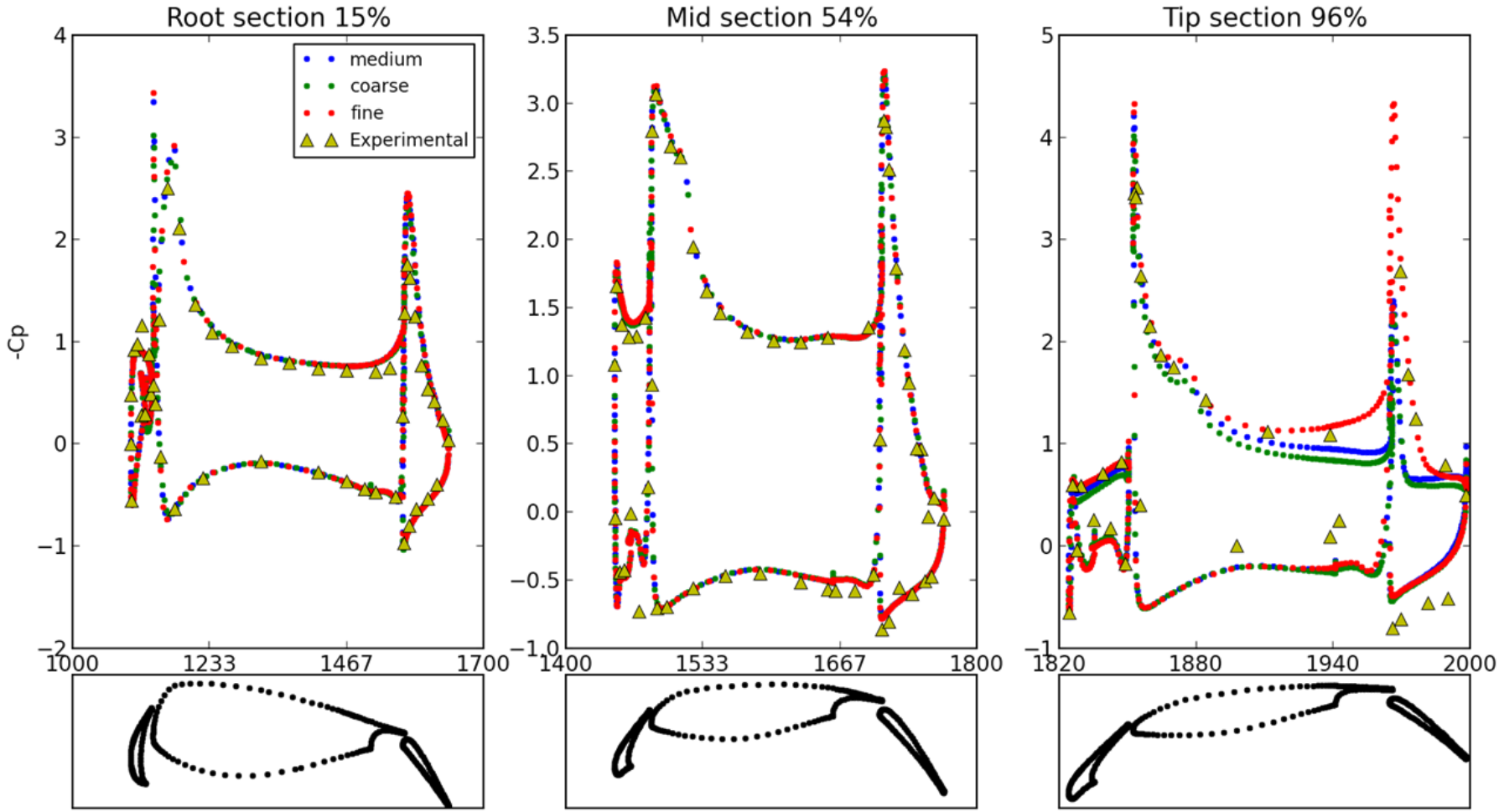
Case 1 – Grid sensitivity

-Cp plots, C1, SA at $\alpha = 7^\circ$



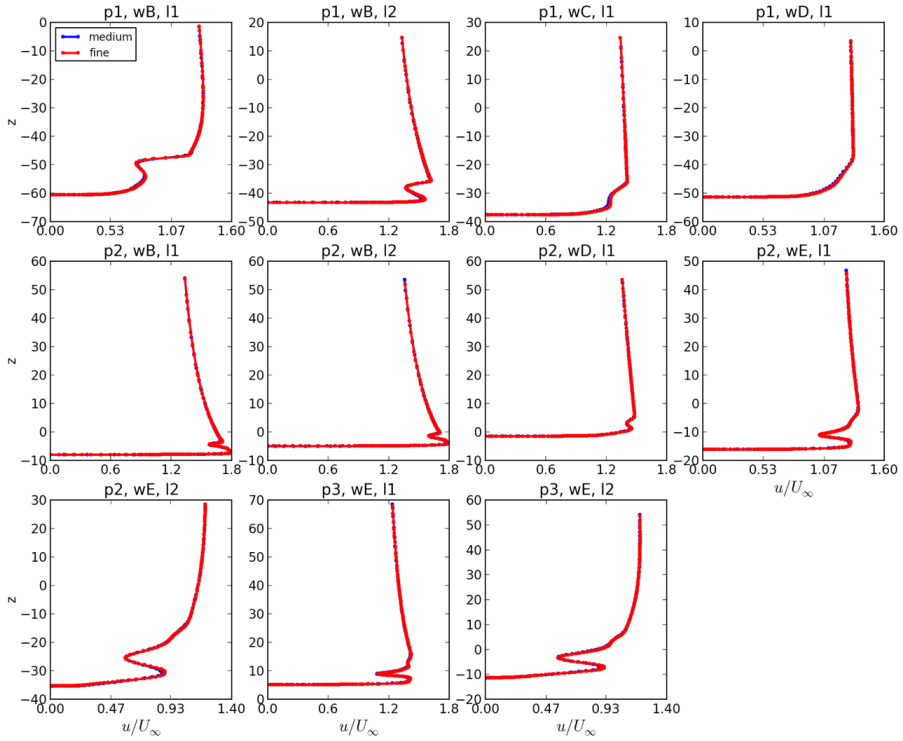
Case 1 – Grid sensitivity

-Cp plots, C1, SST at $\alpha = 7^\circ$

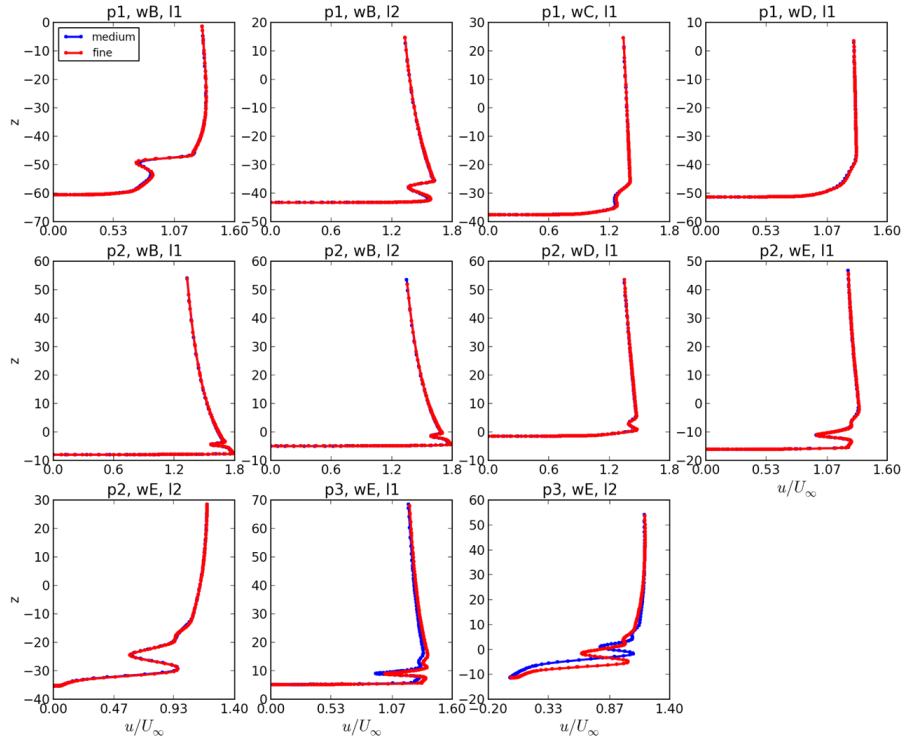


Case 1 – Grid sensitivity
Velocity profiles 7°

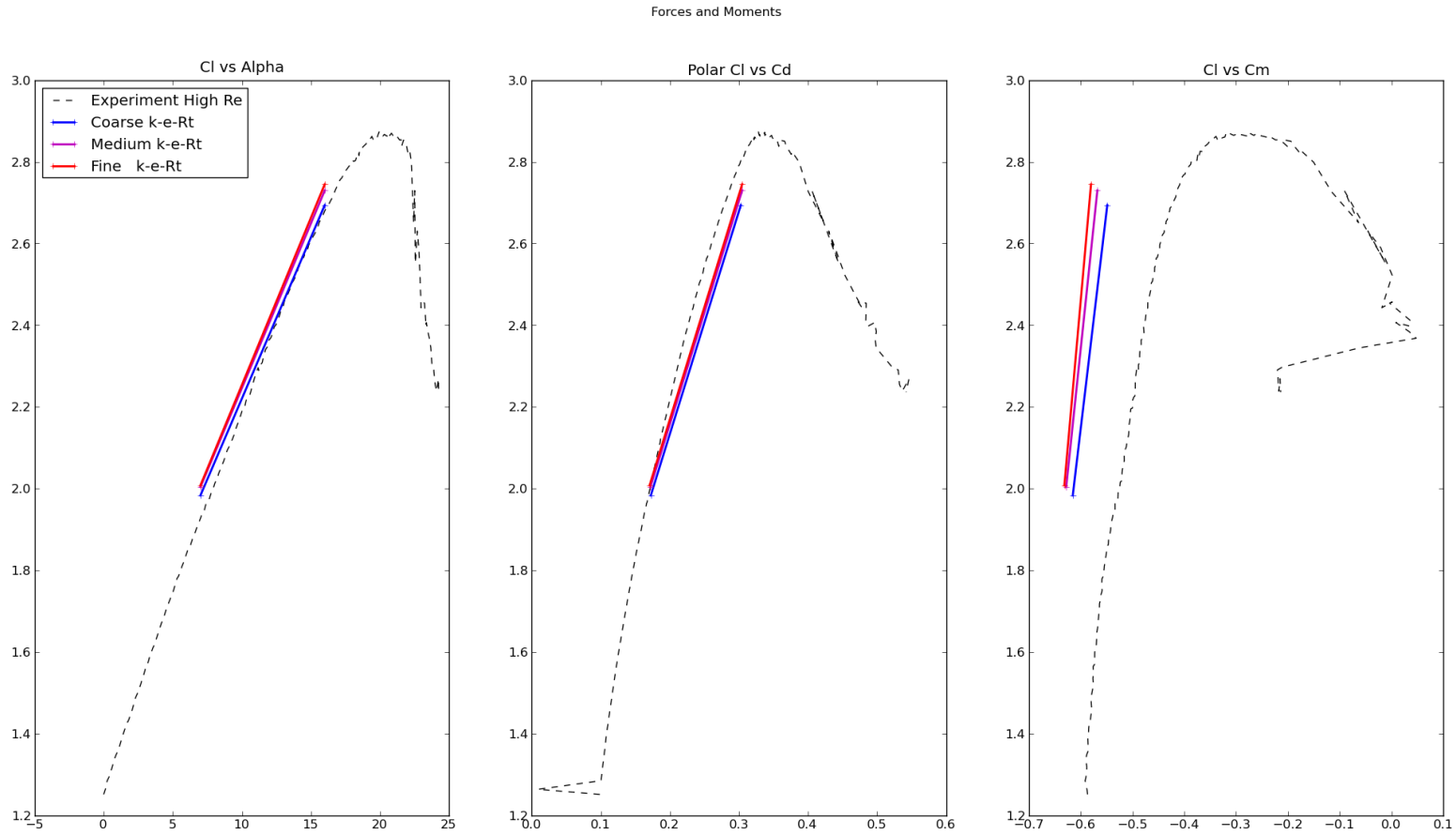
k-ε-Rt



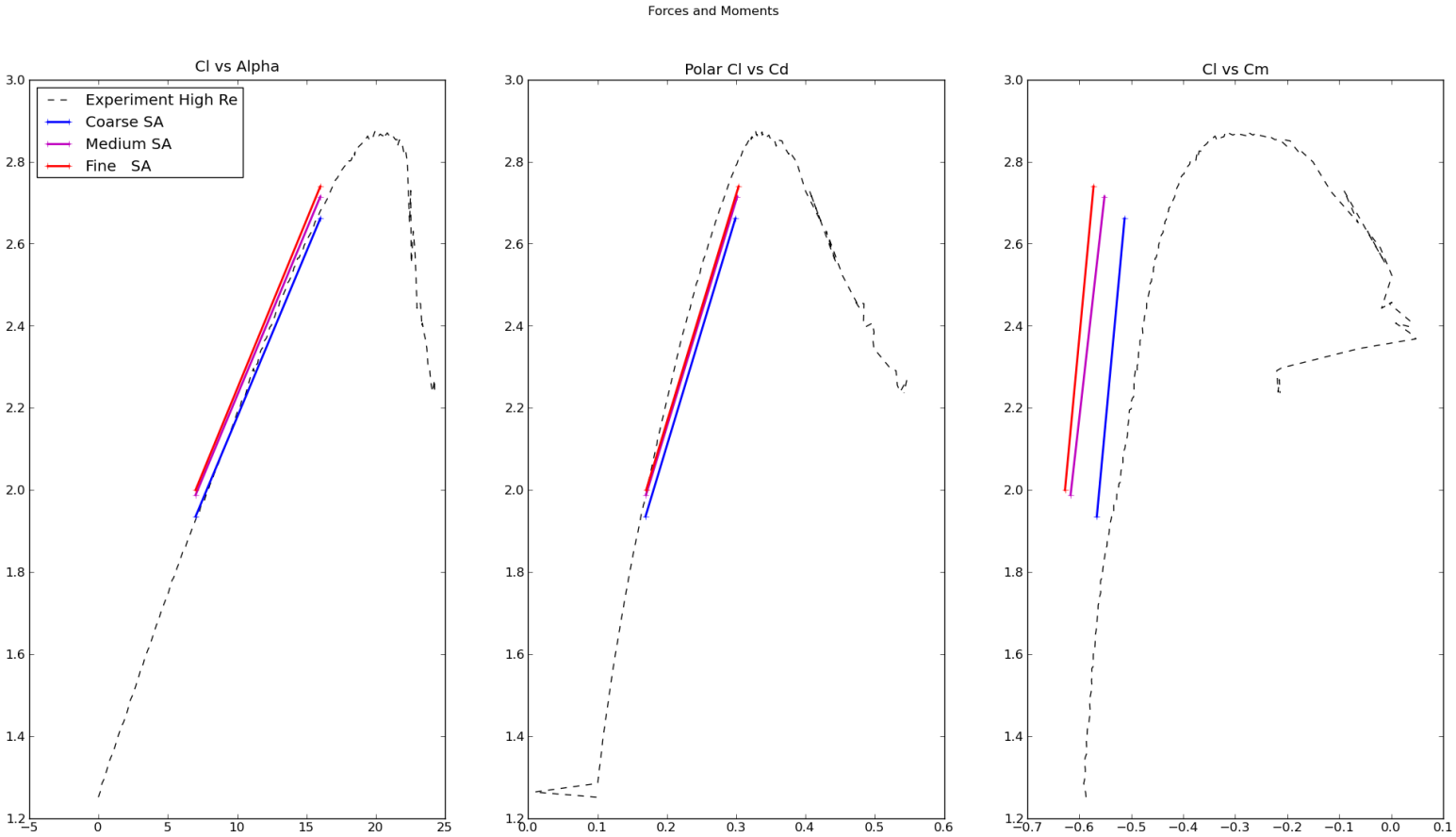
SST



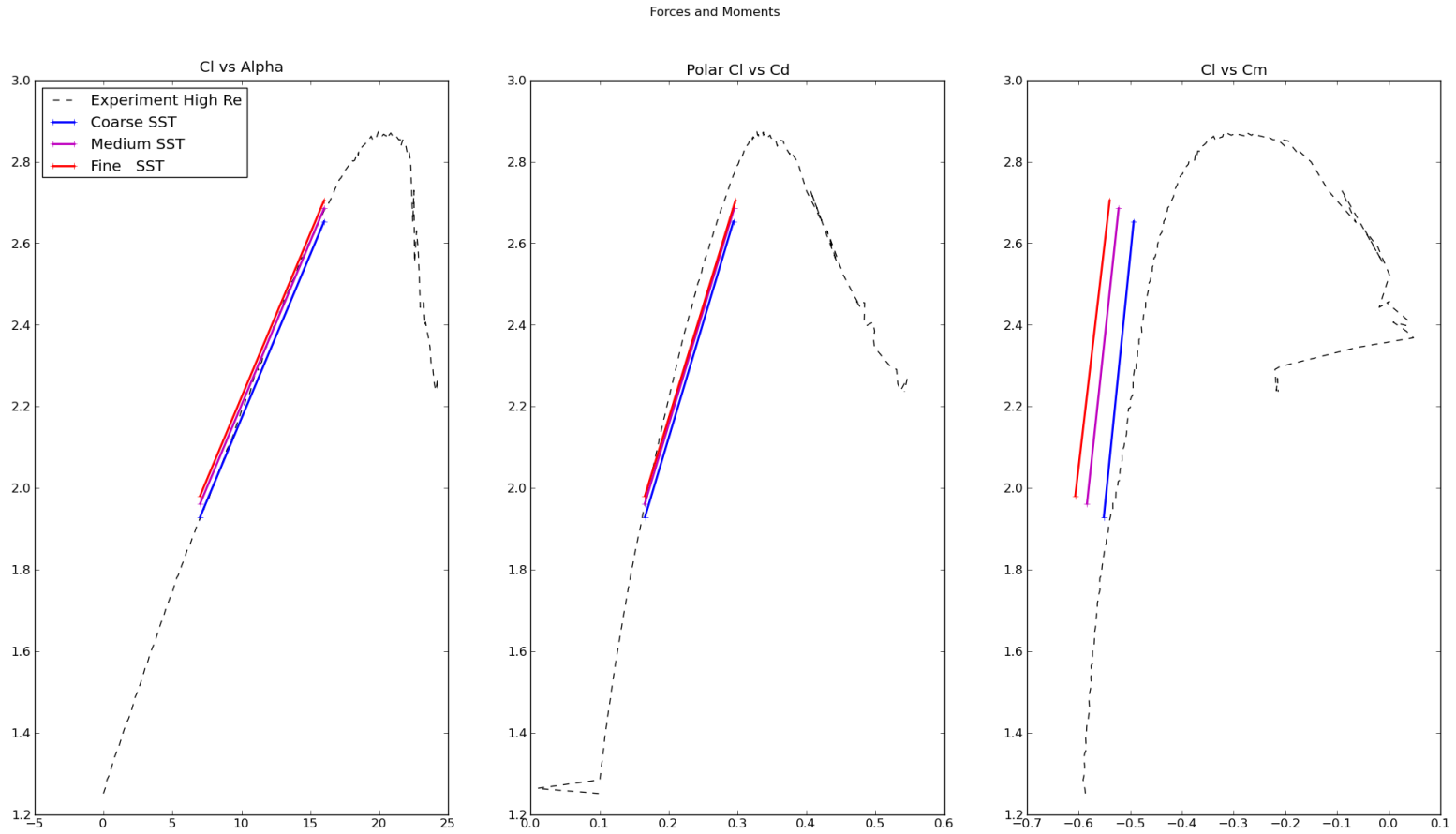
Case 1 – Grid sensitivity – k-ε-Rt



Case 1 – Grid sensitivity - SA



Case 1 – Grid sensitivity - SST



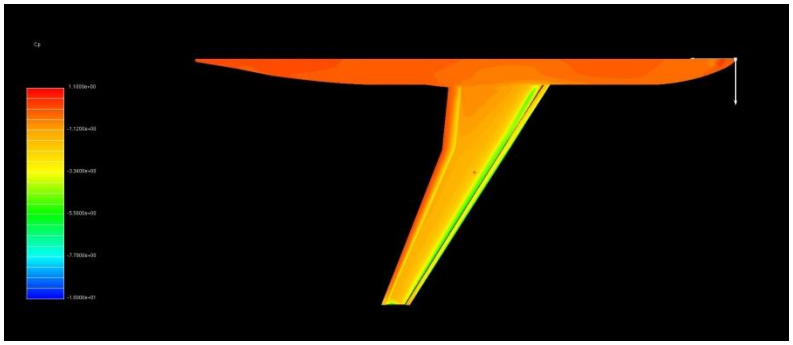
Case 1 – Effect of preconditioning

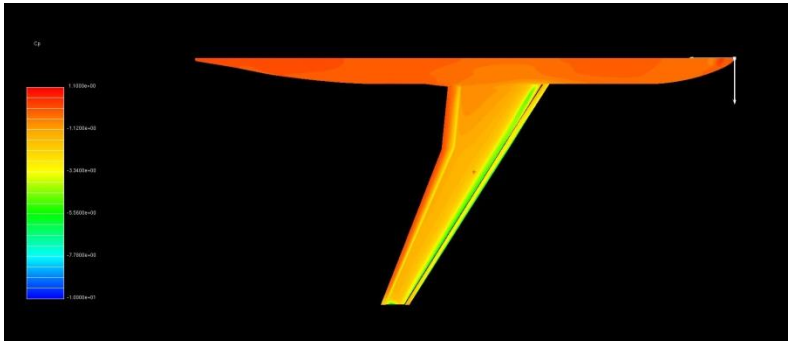
- As a unique exercise for this Workshop we ran both pre-conditioned and non-preconditioned modes to answer the often asked questions:
  1. What is the effect of pre-conditioning?
  2. Which approach is better?
- Both modes were used on coarse, medium and fine grids
- As expected, *preconditioned results show better and faster grid convergence*
- On the finest meshes, non-preconditioned results edge toward the preconditioned ones as seen in the following slides

Case 1 – Effect of preconditioning

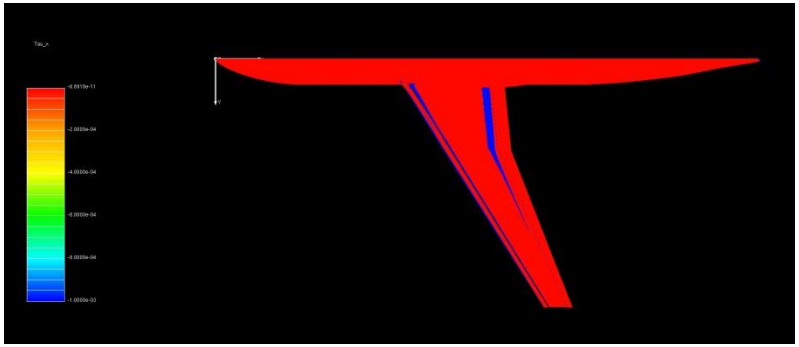
SA Model, Fine mesh

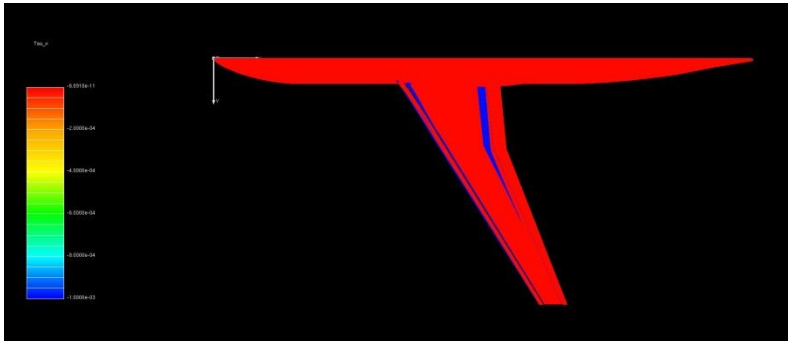
- Non-preconditioned
- Preconditioned





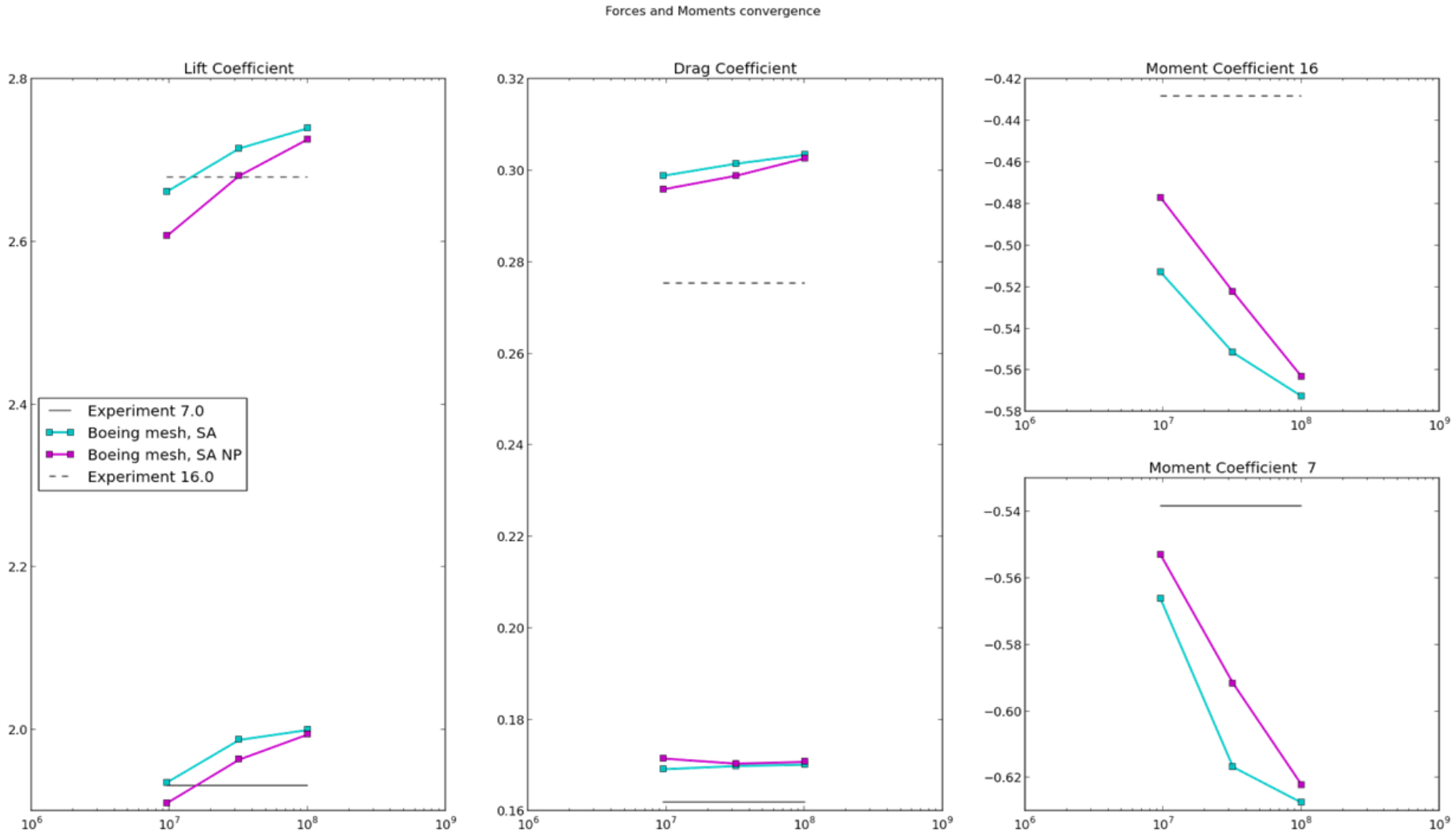
Upper Cp





Lower τ_x

Case 1 – Effect of preconditioning



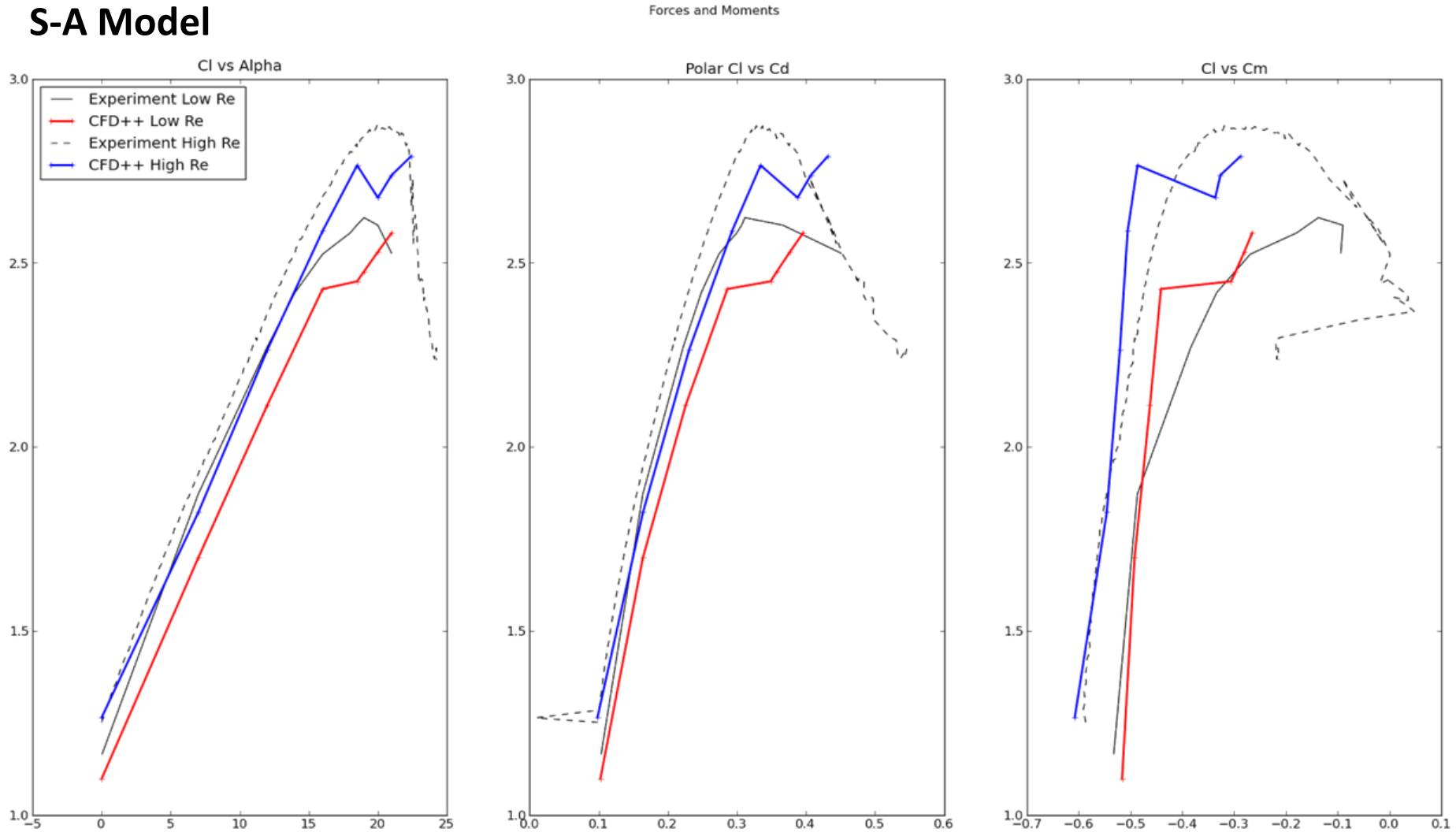
Case 2 – Forces and Moments

- Prisms/Tets mesh (medium grid)
- Pointwise (C_uns_mix_Case2Config4_v1)

MESH	No. of cells
Medium	149,963,804

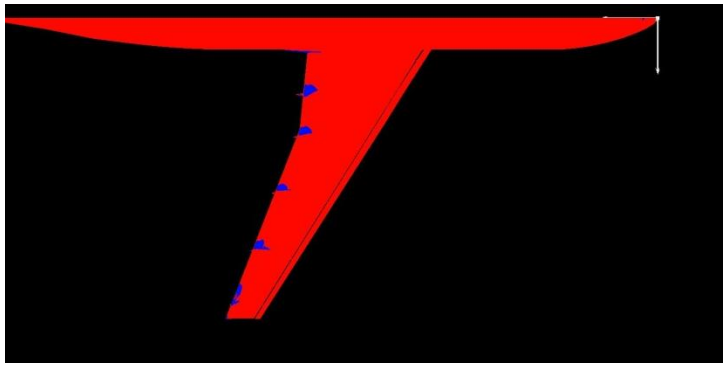
Case 2 – Forces and Moments

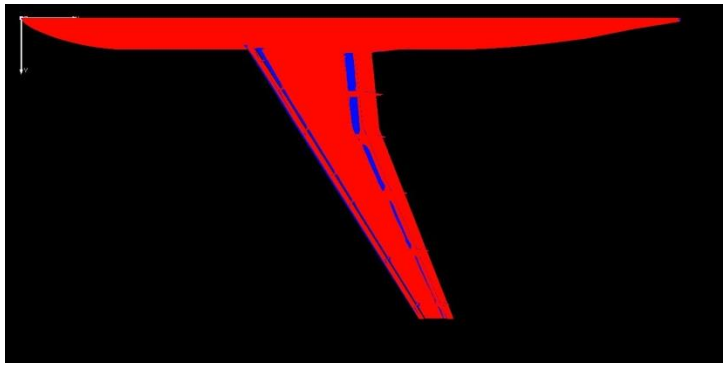
S-A Model



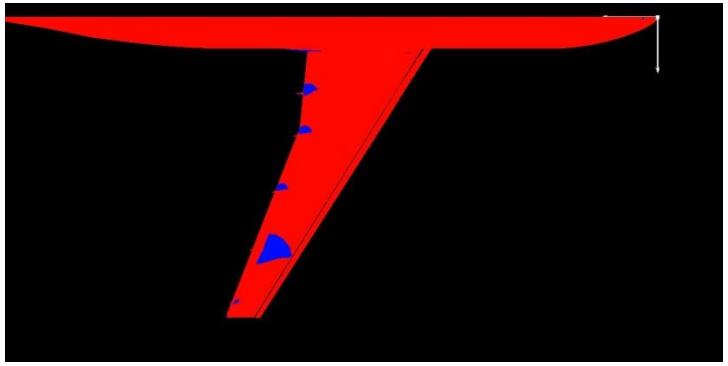
Case 2a (Low Re) – τ_x

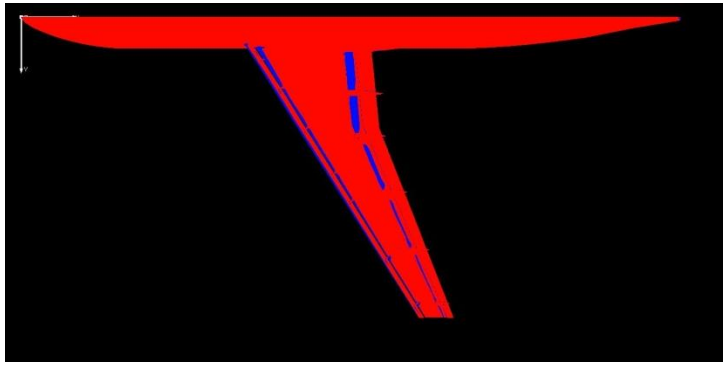
16.0°



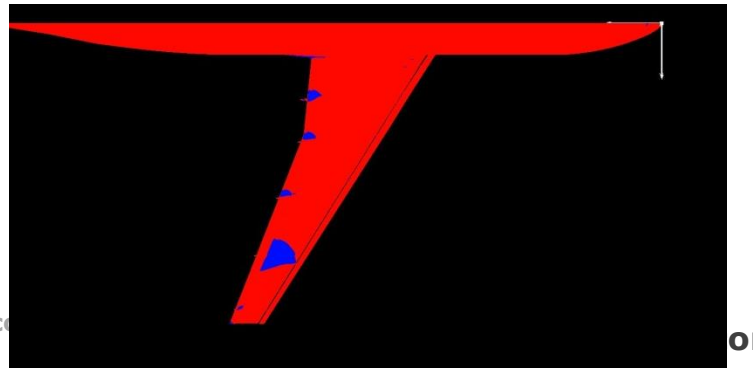


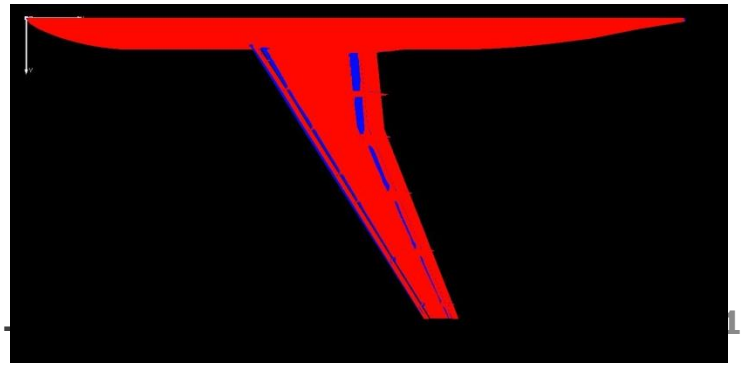
18.5°



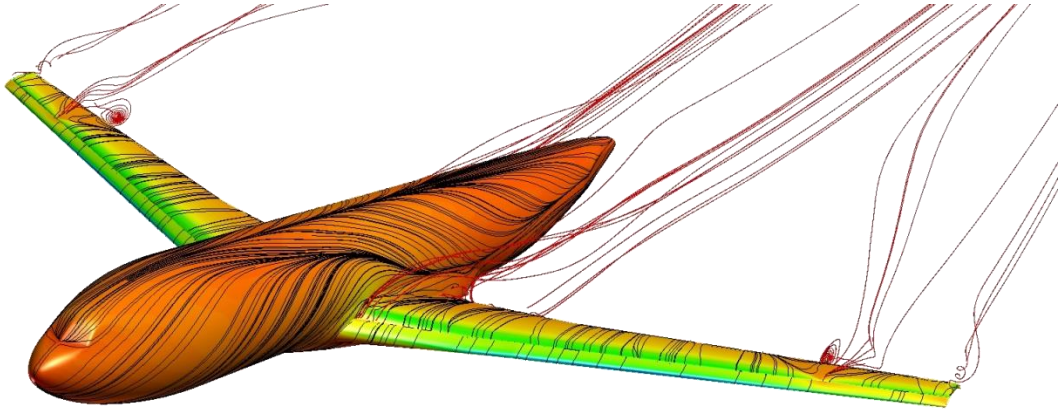


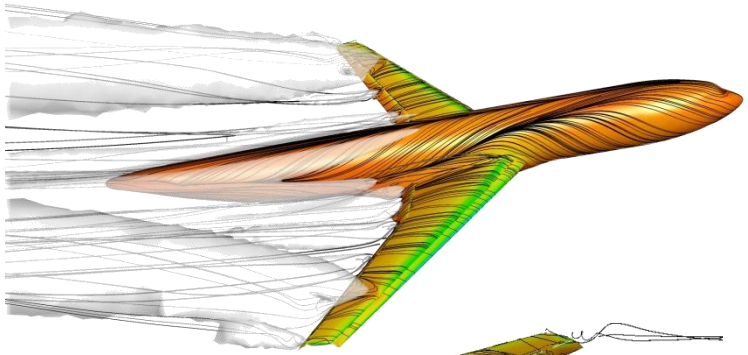
20.0°

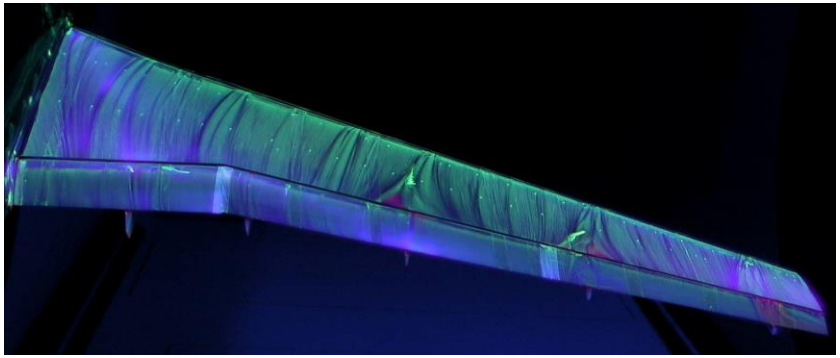


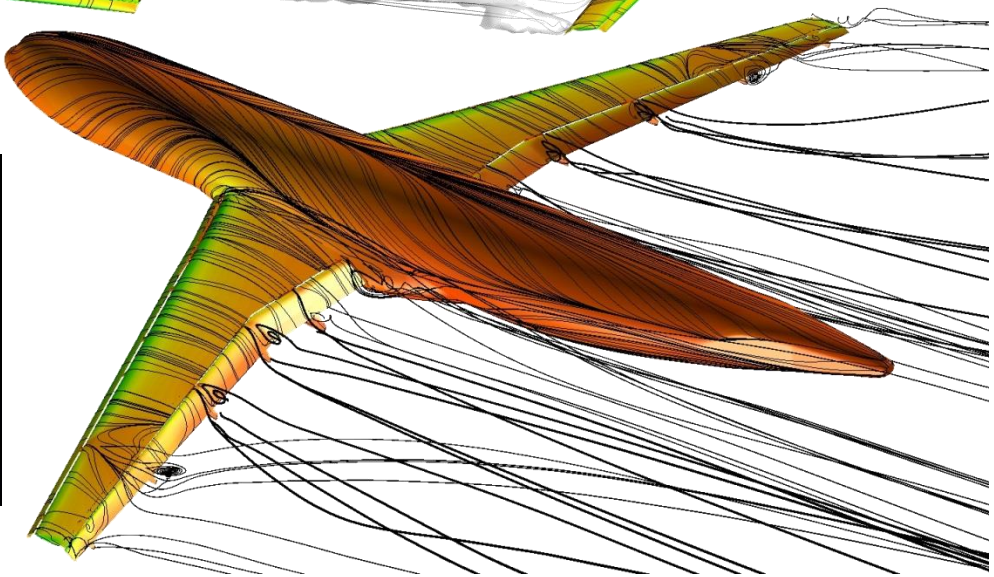


Case 2a (Low Re) – 18.5°



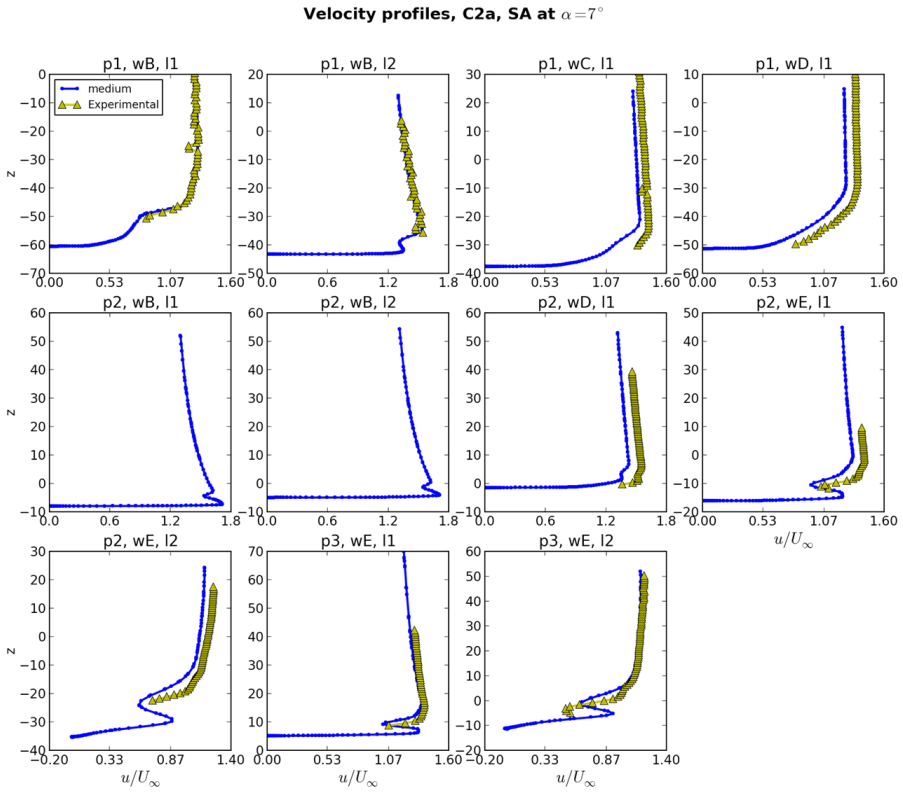




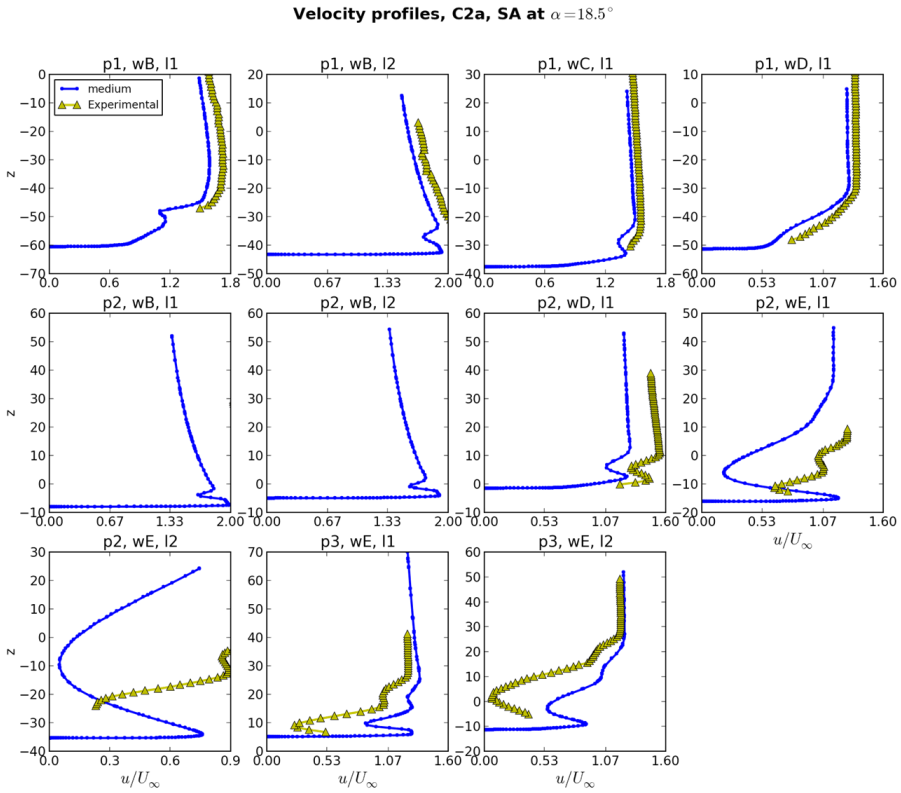


Case 2a (Low Re) – Velocity profiles

7°

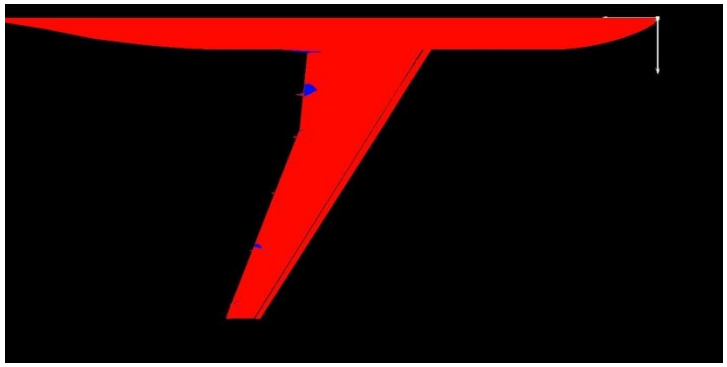


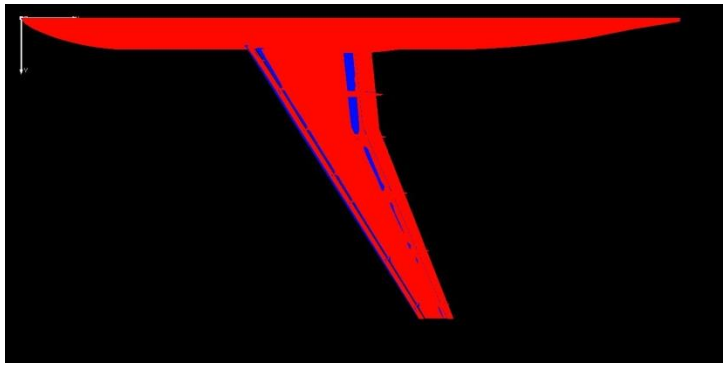
18.5°



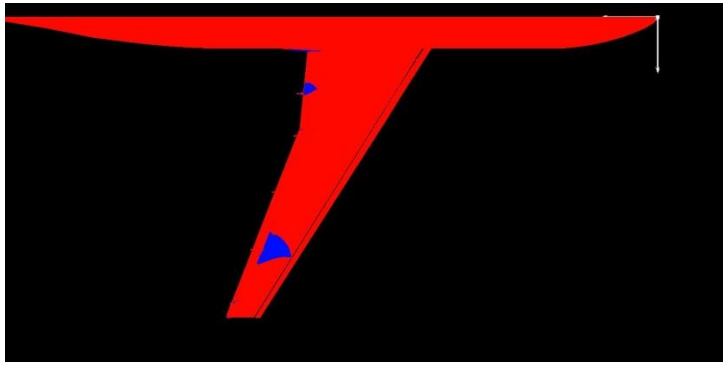
Case 2b (High Re) – Forces and Moments

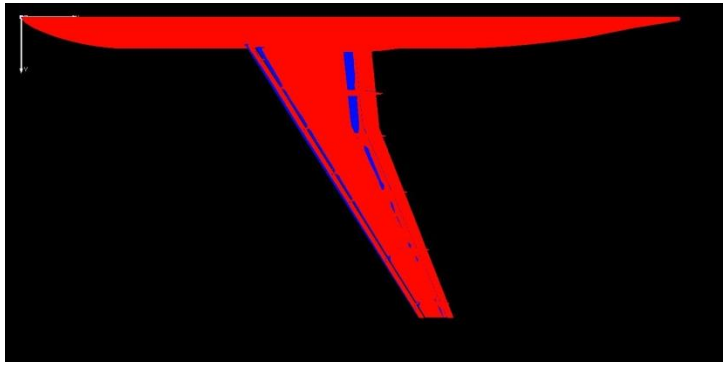
18.5°



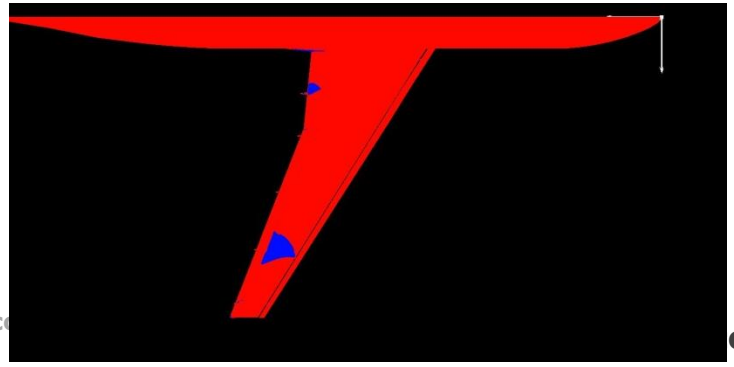


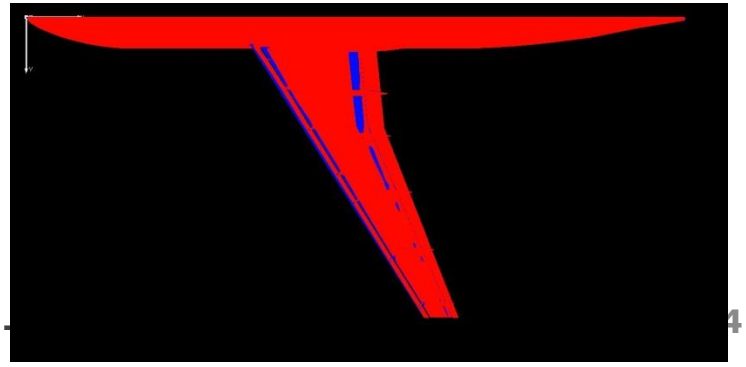
20.0°





21.0°





Conclusions

- CFD++ used in various configurations for C1, C2a and C2b.
  - Effects of turbulence model (k-ε-R_t , SST and S-A)
  - Effects of preconditioning (RHS)

  None is ever a clear outlier in the workshop

- Able to observe grid convergence with all turbulence models
  k-ε-R_t exhibits the least dependence on the grid

- Usefulness of preconditioning at low speed demonstrated

- High Re predictions closer to experiment than Low Re, might be linked to transitional effects being ignored

→ More results, complete Cp plots and velocities profiles in paper